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SULFUR CONTENT OF UPLAND AND WETLAND VEGETATION IN NORTH CENTRAL MINNESOTA

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M. Dean Knighton, *Plant Ecologist,*
Grand Rapids, Minnesota

ABSTRACT.—The sulfur concentration in 138 plant taxa is reported. Significant differences in concentration are noted between some plant life forms and between different environments.

KEY WORDS: sulfur cycle, plant life-form, flora, Lake States, acid precipitation.

Industrial and domestic emissions continue to pour into our atmosphere with little understood consequences (Dochinger and Seliga 1976). These emissions contain sulfur and other elements that increase the acidity, or hydrogen ion activity in precipitation. To improve our understanding of how this "acid rain" affects upland and wetland ecosystems in North America, we need to learn more about the sulfur cycle. We also need to identify all related information, and make it readily available. At the Forestry Sciences Laboratory in Grand Rapids, Minnesota, we have been analyzing the sulfur content of vegetation as part of a larger nutrient study. However, because of the urgent need to better understand the sulfur cycle we are publishing this data immediately in its simplest form.

METHODS

The vegetation was collected from seven water impoundments and one natural deep marsh on the Chippewa National Forest in August of 1976, 1977, and 1978. Samples were collected from 24 1-m^2 systematically located plots in each wetland. The plots were located on transects that extended from 90 cm-deep water to a point 60 cm above the normal water level. All vegetation was clipped on each plot (including woody species less than 2.5 cm at the base), placed in a plastic bag, and transported to the laboratory where it was either frozen immediately or kept at about 3°C for up to 2 weeks before sorting by species. The vegetation was sorted and ovendried for 48 hours at 80°C, and then each species was composited. The composited sample was ground in a Wiley mill and thoroughly mixed, then subsampled for analysis. The foliage and wood of woody species were ground together. The analysis was performed at the Research Analytical Laboratory at the University of Minnesota in St. Paul, Minnesota. Digestion was done by nitric and perchloric acids and SO_4 (later converted to S) content determined turbidmetrically with barium chloride (Blanchar *et al.* 1965).

The samples included the natural mineral and biotic material that adheres to submerged plant surfaces. When using and interpreting the data keep in mind this source of sulfur that could not be partitioned.

The species were grouped by life form, and mean sulfur contents were tested for significant differences (α0.05) by analysis of variance and least significant difference methods. Also, values for individual species within life form groups were compared, using simple regression, with values reported for these species by Gerloff *et al.* (1964) in Wisconsin.

DISCUSSION

Differences in mean sulfur content were significant only between woody and nonwoody plants (table 1). In South Carolina, Boyd (1978) grouped wetland species by life form and reported sulfur contents of 0.31, 0.18, and 0.24 percent for submerged, floating-leaved, and emergent life forms, respectively. These values are remarkably similar to ours (0.31, 0.16, and 0.23 percent), suggesting that real differences may exist in these life forms but that more information is needed to increase statistical sensitivity.

Table 1.—*Sulfur content of impoundment vegetation summarized by life form groups*

(In percent)

Life form	Mean sulfur content and 95 percent confidence interval	Species (n)
Nonwoody		
Submergents	0.31 ± 0.06	4
Floating-leaved	0.16	2
Emergents	0.23 ± 0.03	65
Terrestrial	0.21 ± 0.05	27
Woody		
Shrubs	0.10 ± 0.03	25
Trees	0.10 ± 0.02	15

[1]Means are significantly different (α 0.05) between woody and nonwoody groups.

The low sulfur content of shrubs and trees was expected because woody tissue is known for its low sulfur content (Remezov *et al.* 1955). An accurate estimate of sulfur in these species will require partitioning (Young and Carpenter 1967) of the biomass into various components, particularly if they exceed the 2.5 cm basal diameter included in our study.

Our data showed trends similar to those of Gerloff *et al.* in Wisconsin (table 2). Most notable is the indication that emergent species common on submerged to poorly drained soils contain more sulfur than species commonly found on drier sites. Although this observation is supported by Siccama *et al.* (1970) who report a 0.20 percent mean sulfur content for terrestrial vegetation, it must be viewed cautiously in light of Bowen's (1966) report of a 0.34 percent mean for terrestrial vegetation. The values found by Gerloff *et al.* for each life form represented also tend to be higher than the values we found, perhaps because of different analytical methods. When the two data sets were compared species-to-species within groups, no regression coefficient was significantly different from zero (α0.05). This result emphasizes the extreme variability of the data and indicates that use of the life form mean for all species within the group is as reliable as individual species values.

Table 2.—*Sulfur content of species common to both the present study and to the Wisconsin study by Gerloff* et al. *(1964)*

(In percent)

Life form	Mean sulfur content and 95 percent confidence interval		Species (n)
	Knighton	Gerloff	
Nonwoody			
Submergents	-	-	0
floating-leaved	-	-	0
Emergents	0.18 ± 0.10	0.26 ± 0.16	9
Upland[1]	0.12 ± 0.06	0.21 ± 0.05	17
0.06			
Woody			
Shrubs	0.09 ± 0.02	0.11 ± 0.06	10
Trees	0.08 ± 0.02	0.08 ± 0.03	6

[1]Means are significantly different (α 0.05).

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APPENDIX

Sulphur content of plant species in and around water-impoundments of north central Minnesota. Species names are in accordance with Gleason (1968).

(In percent)

Species	Sulfur 1976	1977	1978	Mean
SUBMERGENTS				
Ceratophyllum demersum L.	0.34	-	0.40	0.37
Myriophyllum exhalbescens Fern.	-	0.29	0.33	0.31
Potamogeton spp. L.	0.29	0.34	0.21	0.28
Utricularia vulgaris L.	0.26	0.25	0.38	0.30
FLOATING-LEAVED				
Nuphar variegatum Engelm.	-	-	0.12	0.12
Nymphaea tuberosa Paine.	0.24	0.23	0.09	0.19
EMERGENTS				
Acorus Calamus L.	0.24	0.19	0.12	0.18
Agrostis ssp. L.	0.23	-	-	0.23
Alopecurus Aequalis Sobol.	0.29	-	-	0.29
Bidens spp. L.	0.23	0.16	0.28	0.22
Calamagrostis canadensis (Michx.) Beauv.	0.13	-	-	0.13
Calamagrostis inexpansa Gray.	0.15	-	-	0.15
Calamagrostis neglecta (Ehrh.) Gaertn.	0.13	-	-	0.13
Campanula aparinoides Pursh.	0.16	-	-	0.16
Carex spp. L	0.16	0.15	0.17	0.16
Carex comosa Boott.	0.17	-	-	0.17
Carex lasiocarpa Ehrh.	0.13	-	-	0.13
Carex Pseudo-Cyperus L.	0.14	-	-	0.14
Carex rostrata Stokes.	0.15	-	-	0.15
Carex suberecta (Olney) Britt.	-	0.16	-	0.16
Chenopodium album L.	0.31	-	-	0.31
Cicuta bulbifera L.	0.32	0.25	-	0.28
Dulichium arundinaceum (L.) Britt.	-	0.20	0.12	0.16
Eleocharis spp. R.Br.	-	0.22	0.12	0.17
Epilobium adenocaulon Haussk.	0.19	0.24	-	0.22
Equisetum fluviatile L.	0.19	-	-	0.19
Equisetum palustre L.	0.27	-	-	0.27
Eupatorium maculatum L.	0.31	-	-	0.31
Eupatorium perfoliatum L.	-	-	0.15	0.15
Galium spp. L.	280.32	0.14	0.25	
Geum spp. L.	0.14	-	-	0.14
Glyceria borealis (Nash) Batchelder	0.21	-	-	0.21
Glyceria canadensis (Michx.) Trin.	0.39	-	-	0.39
Glyceria grandis S.Wats.	0.25	-	-	0.25
Glyceria septentrionalis Hitchc.	0.17	-	-	0.17
Impatiens biflora Willd.	0.30	0.32	0.27	0.30
Iris versicolor L.	0.15	0.13	0.10	0.12
Laportea candensis (L.) Gaud.	0.76	-	-	0.76

Species	Sulfur 1976	1977	1978	Mean
EMERGENTS (con't)				
Leersia oryzoides (L.) Sw.	0.20	-	-	0.20
Lycopus americanus Muhl.	0.35	0.36	0.29	0.33
Lycopus uniflorus Michx.	0.27	0.18	0.17	0.24
Mentha arvensis L.	0.36	0.27	0.10	0.24
Naumburgia thyrisiflora L.Duby.	0.19	-	0.15	0.17
Phalaris arundinacea L.	0.14	0.20	0.32	0.22
Phragmites communis Trin.	0.11	-	0.36	0.24
Poa spp. L.	0.09	-	0.18	0.14
Polygonum cilinode Michx.	0.15	0.15	0.13	0.14
Polygonum lapathifolium L.	0.14	0.36	-	0.21
Polygonum natans Eat.	0.24	0.20	0.18	0.21
Potentilla palustris (L.) Scop.	0.13	0.13	0.12	0.13
Ranunculus Gmelini DC.	0.33	0.29	-	0.31
Ranunculus pensylvanicus L.f.	0.20	0.24	-	0.22
Rorippa islandica (Oeder) Borbas.	0.38	-	-	0.38
Rumex spp.L.	-	0.12	-	0.12
Sagittaria latifolia Willd.	0.18	-	0.20	0.19
Scirpus americanus Pers.	-	-	0.17	0.17
Scirpus cyperinus (L.) Kunth.	0.21	0.21	-	0.21
Scirpus subterminalis Torr.	-	0.21	-	0.21
Scirpus validus Vahl.	0.23	-	-	0.23
Scutellaria galericulata L.	0.22	0.27	-	0.24
Scutellaria lateriflora L.	0.26	-	0.22	0.24
Sium suave Walt.	0.65	0.46	0.25	0.45
Solidago spp. L.	0.15	0.12	0.24	0.17
Sparganium fluctuans (Morong.) Robins.	0.29	-	-	0.29
Stachys palustris L.	0.17	0.15	0.19	0.17
Triadenum virginicum (L.) Raf.	0.18	0.35	-	0.27
Typha latifolia L.	0.14	0.18	0.13	0.15
Urtica dioica L.	0.52	0.35	-	0.44
Zizania aquatica L.	0.17	0.09	0.28	0.18
TERRESTRIAL				
Anemone ssp. L.	0.35	0.44	-	0.40
Apocynum androsaemifolium L.	-	0.40	-	0.40
Aralia nuducaulis L.	0.16	0.18	0.14	0.16
Aster spp. L.	0.18	0.09	-	0.13
Aster cordifolius L.	-	0.08	-	0.08
Aster macrophyllus L.	0.14	0.11	0.13	0.12
Athyrium Filix-femina (L.) Roth.	0.19	-	-	0.19
Cirsium arvense (L.) Scop.	0.30	0.56	0.25	0.37

Species	Sulfur 1976	1977	1978	Mean
TERRESTRIAL (con't)				
Clintonia borealis (Ait.) Raf.	-	-	0.12	0.12
Cornus canadensis L.	0.25	0.25	0.21	0.24
Dryopteris ssp. Adans.	0.25	0.13	-	0.19
Fragaria spp. L.	0.14	0.14	0.09	0.12
Galium triflorum Michx.	0.19	0.19	-	0.19
Geranium Robertianum L.	-	0.44	-	0.44
Heracleum lanatum Michx.	0.56	-	-	0.56
Lactuca canadensis L.	0.14	0.15	-	0.14
Lathyrus spp. L.	0.34	0.17	-	0.26
Lycopodium obscurum L.	0.12	-	0.12	0.12
Maianthemum canadense Desf.	0.17	0.35	0.15	0.22
Osmunda Claytoniana L.	-	-	0.17	0.17
Parthenocissus quinquefolia (L.) Planch.	-	0.13	-	0.13
Pteridium aquilinum (L.) Kuhn.	0.14	0.10	0.06	0.10
Smilacina trifolia (L.) Desf.	0.12	0.11	-	0.12
Streptopus roseus Michx.	-	-	0.24	0.24
Thalictrum dioicum L.	-	0.13	0.20	0.16
Uvularia grandiflora Sm.	0.15	-	-	0.15
Viola spp. L.	0.23	0.16	-	0.19
SHRUBS				
Alnus rugosa (DuRoi) Spreng.	-	0.08	0.08	0.08
Amelanchier spp. Medic.	0.02	0.04	0.05	0.04
Arctostaphylos Uva-ursi (L.) Spreng.	0.14	-	-	0.14
Cornus stolonifera Michx.	0.31	0.12	0.10	0.18
Corylus americana Walt.	0.05	0.05	-	0.05
Corylus cornuta Marsh.	-	0.05	0.02	0.04
Dead shrub	-	0.05	0.02	0.04
Diervilla Lonicera Mill.	0.08	-	-	0.08
Lonicera spp. L.	0.31	-	-	0.31
Ostrya virginiana (Mill.) K. Koch.	0.05	-	-	0.05

Species	Sulfur 1976	1977	1978	Mean
SHRUBS (con't)				
Rhamnus alnifolius L'Her.	-	0.05	-	0.05
Ribes spp. L.	0.10	0.13	0.12	0.12
Rosa spp. L.	0.10	-	0.04	0.07
Rubus spp. L.	-	0.17	0.07	0.12
Salix spp. L.	0.06	0.14	0.08	0.10
Salix Bebbiana Sarg.	0.05	-	-	0.05
Salix discolor Muhl.	0.12	-	-	0.12
Salix petiolaris Sm.	0.16	-	-	0.16
Salix rigida Muhl.	0.13	-	-	0.13
Spiraea spp. L.	0.08	-	0.06	0.07
Vaccinium myrtilloides Michx.	-	0.12	0.51	0.32
Vaccinium angustfolium Ait.	-	0.12	-	0.12
Viburnum Lentago L.	-	0.06	-	0.06
Viburnum Rafinesquianum Schult.	0.06	0.06	0.07	0.06
Viburnum Opulus L.	0.07	-	-	0.07
TREES				
Abies balsamea (L.) Mill.	-	-	0.06	0.06
Acer rubrum L.	-	0.08	0.10	0.09
Acer saccharum Marsh.	0.03	0.17	0.07	0.09
Acer spicatum Lam.	-	0.07	-	0.07
Betula papyrifera Marsh.	-	0.07	-	0.07
Dead tree	-	0.09	-	0.09
Fraxinus nigra Marsh.	-	0.11	-	0.11
Picea mariana (Mill.) BSP.	0.05	-	-	0.05
Populus balsamifera L.	0.08	0.07	0.05	0.06
Populus tremuloides Michx.	0.08	0.11	0.04	0.08
Prunus pensylvanica L. f.	-	0.08	-	0.08
Prunus virginiana L.	-	0.02	0.33	0.18
Quercus macrocarpa Michx.	-	0.07	-	0.07
Quercus borealis Michx. f.	-	0.13	-	0.13
Ulmus americana L.	-	0.11	0.27	0.19

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